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Sports participation and the solitary kidney, with particular reference to the child athlete

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Abstract

The aims of this systematic review were to analyze the risks of renal injury during various sports and to recommend appropriate management with particular reference to individuals with a solitary kidney. The Ovid/Medline data-base was searched from 1996 to August 2015. The terms sports/sports medicine, athletes or physical activity were combined with the terms wounds and injuries/kidneys to yield 27 citations relevant to the review. This data base was supplemented extensively from journal reference lists and the author's personal files to provide a total of 56 citations. Review articles suggest that many physicians are still very cautious in recommending some forms of sport to children with single kidneys, while permitting other more dangerous activities. The absolute risks of renal injury are very low but not non-existent for most sports; for instance, there are 2.6 incidents per million exposures in male soccer players. Many renal injuries are minor, and only a small minority require nephrectomy. Contact sports account for perhaps a fifth of physical activity-related renal trauma, but the operation of all-terrain vehicles, cycling, Alpine sports and horse-back riding are all more common sources of injury. Possible factors modifying inherent risks include parental supervision, the wearing of protective equipment, initial renal health, and the individual's age (children being more vulnerable than adults). Minor renal injuries may require only 2-6 weeks of restricted activity; often, there are no long-term consequences, but subcapsular haematomas can cause a pressure necrosis of renal tissue, with later risks of hypertension, proteinuria and renal insufficiency. Sports physicians must communicate the objective level of risk to the parents of children with a single kidney, emphasizing that sport carries greater dangers for the head than the kidneys, and that serious renal injury is more likely from motor traffic than from sport participation. Moreover, they must underline the importance of continued regular physical activity to the overall health and development of the child. Nevertheless, they should also underline the need to take all reasonable precautions to reduce risk, including the avoidance of activities likely to involve collisions and blunt trauma.

Key words: Alpine sports, All-terrain vehicles, Contact sports, Cycling, Horse riding, Renal agenesis

Introduction

The main causes of a unilateral kidney include (1) a birth defect (renal agenesis, affecting between 1 in 500 and 1 in 1800 infants)(Anderson, 1995), (2) surgical removal of a kidney (for a neoplasm, injury or disease), and (3) kidney donation. It is important to maintain the health of the remaining kidney, and participation in regular physical activity can in itself contribute to this

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process by reducing the risk of hypertension, diabetes mellitus and other kidney-damaging chronic diseases. However, many physicians remain reluctant to permit individuals with a single kidney to participate in sport, particularly if body contact is involved, because of the perceived risk of renal trauma that requires nephrectomy, leading to regular dialysis and the search for a renal transplant. A survey of members of the American Society of Pediatric Nephrology found that 86% of respondents banned children with a single kidney from American football, although only 5% prohibited cycling (Grinsell, Showalter, Gordon, & Norwood, 2006). A similar survey of the Urology Section of the American Academy of Pediatrics found 68% of members banning contact sports for patients with a single kidney (Sharp, Ross, & Kay, 2002). Again, only 41.6% of members of the American Medical Society for Sports Medicine would allow one of their own children with a solitary kidney to practice unrestricted sports (Anderson, 1995; MacAuley & Best, 2008). In Italy, a medical certificate is required in order to participate in any type of organized sport, and certification is currently denied to anyone with a solitary kidney (Spreafico et al., 2014).However, the American Academy of Pediatrics (Rice, 2008) and the American and the Canadian Urological Associations (Psooy, 2014) have all recently adopted more permissive stances.

In view of current conflicting opinions on the risks of renal injury in sport and the management of children with a single kidney, the present review makes a systematic assessment of current evidence on the risks associated with various types of sport. Specific issues that are addressed include (1) current attitudes to sport for those with a single kidney, (2) the overall risk of renal injury during sports, (3) the extent to which this risk is modified by various factors including the absence of one kidney, (4) the specific risk of renal injury in contact sports, (5) the types of sport presenting the greatest risk of renal injury, (6) issues arising during the performance of specific sports, and (7) the management of such injuries.

Methods

The Ovid/Medline data base was searched from January 1996 to August 2015, using the keywords "sports/sports medicine" (97075 hits), "athletes" (4404) OR "physical activity" (48470) to yield 137,880 unique citations. Unrestricted combination with the terms "wounds and injuries/kidneys" (1661) yielded 46 citations. All 46 abstracts were reviewed; 10 papers covered various aspects of renal injury, and 17 provided factual observations on the incidence of renal injuries and their management. A further 7 articles on ureteric rupture, and 12 papers discussing other topics unrelated to the review were discarded. The primary information base of 27 articles was extensively supplemented from the author's personal files and a scanning of journal reference lists to yield a total of 56 relevant citations.

Results and Discussion

Current attitudes to sport participation for individuals with a solitary kidney

Despite many review articles making recommendations concerning sport for the individual with a solitary kidney (Table 1), an article published in 2005

underlined that there was as yet no consensus on an appropriate policy (Patel, Torres, & Greydanus, 2005). Several reports from the American Academy of Pediatrics (Dyment, 1988; Rice, 2008; Risser, 1994; Sharp et al., 2002; Washington, 2001) recognized that if such individuals participated in contact sports, the risk was very low; nevertheless (perhaps because of fear of litigation), recommendations remained very cautious. Psooy (2006, 2009, 2014) underlined that the risk of injury to the head was far greater than the risk of injury to a solitary kidney; she thus argued that sport should be allowed, although with careful and documented explanation of risks to both the participant and the next of kin. Other authors who made a careful analysis of injury statistics (Grinsell et al., 2006; Johnson, Christensen,

Table 1. *Summary of recommendations from review articles discussing sport in the patient with a single kidney.*

Author	Information source	Recommendation
Bernard (2009)	Literature review	Sports participation is generally safe, with very minimal risk to the remaining kidney
Dyment (1988)	Consensus of American Academy of Pediatrics	No contact or collision sports
Grinsell et al. (2006)	Search of medical and sports literature data bases	Restricting participation of patients with a single, normal kidney from contact/collision sports is unwarranted
Johnson et al. (2005)	National pediatric trauma registry	Prohibition of contact sports with solitary kidney overly protective, needs to be re-evaluated
Patel et al. (2005)	Review of major articles	No consensus on participation in contact or collision sports by adolescents with one kidney
Psooy (2006, 2009, 2014)	Nine recent articles	Risk of renal injury a fifth of that for head injury; most dangerous sports are bicycling, sledding, downhill skiing/snowboarding and horse-related activities
Rice (2008)	Council on Sports Medicine & Fitness, American Academy of Pediatrics	Athlete needs individual assessment for contact, collision, and limited-contact sports. Protective equipment may reduce risk of injury to the remaining kidney sufficiently to allow participation in most sports, providing such equipment remains in place during activity
Sacco et al. (2010)	Literature review	Sports responsible for 13% of genitourinary trauma, but renal trauma usually Grade I-II, not requiring surgical treatment; significant injury rare if solitary kidney
Sharp et al. (2002)	Survey of American Academy of Pediatrics, Urology Section	68% of respondents recommended no contact sport if solitary kidney, although recognizing that risk low (<1%)
Spreafico et al. (2014)	Study of survivors of renal tumours	Need to avoid lifestyles and behaviours potentially dangerous to remaining kidney; but current Italian blanket prohibition of competitive organized sports unjustified.
Styn & Wan (2010)	Literature review	Risk of sport participation very low, but not zero. No evidence that risk of renal injury greater if solitary kidney
Risser (1994), Washington (2001)	American Academy of Pediatrics, consensus report	Athlete needs individual assessment for contact, collision, and limited-contact sports.

Diusso, Choudhury, & Franco, 2005; Sacco et al., 2010 ; Spreafico et al., 2014; Styn & Wan, 2010) generally concluded that widely prevalent restrictions on sport participation for the child with a single kidney were unwarranted in the face of a very low level of risk. Styn & Wan (2010) further noted that there was no evidence of an over-representation of individuals with solitary kidneys among the reported injuries. The time thus seems ripe for a detailed objective review of risks, and possibly the adoption of a more liberal policy.

Risks of renal injury during sport participation

Despite the fears of many physicians, sport participation accounts for a small fraction of renal injuries (Table 2). Various authors have found recreational sports responsible for from 2 to 28% of renal injuries (Gerstenbluth, Spirnak, & Elder, 2002; Styn & Wan, 2010).

Table 2. The incidence and severity of renal injury during sports participation

Authors	Sample	Findings
Bergqvist et al. (1982)	1354 cases of abdominal trauma in Skaraborg County (Sweden), 1950-1979	59 sport-related injuries to kidneys ; approximate incidence 8 per million person-years, apparently rising. Nephrectomy needed in 2 cases, hemi-nephrectomy in 1 over 30 years.
Gerstenbluth et al., (2002)	68 children with blunt renal trauma (14 due to sport)	5 cycling and 1 sports injuries grade IV or V.
Grinsell et al. (2006)	American Organ Procurement and Transplantation Network	96,000 patients awaiting a renal transplant. None due to sport participation
Grinsell et al. (2012)	U.S. National Athletic Trainers' Association High-School injury survey, 1995 to 1997; 4 million athletic exposures	18 renal injuries, but none resulted in nephrectomy or permanent renal injury. Renal injuries in basketball 2.3 (M), 2.6 (F) per million exposures; soccer 2.5 (M), 6.0 (F) per million exposures. Risk lower than head or spinal injury.
Johnson et al. (2005)	U.S. national pediatric trauma registry, 49,561 cases	92 incidents due to cycling, 88 to sports participation (approximate incidence 8 and 7 per million children-years). Only 4 sports injuries required nephrectomy
McAleer et al. (2002)	San Diego trauma registry 1984-2000, 14763 patients	113 renal injuries due to various physical activities (7 per year); no single-kidney cases, no nephrectomies
Wan et al. (2003a)	Trauma registry, 4921 injured children aged 5-18 yr, Western New York State, 1993-2000	Recreational kidney injury 6.9 per million children-years. Recreational injuries requiring nephrectomy 0.4 per million children-years
Wan et al. (2003b)	National pediatric trauma registry, 81,923 cases aged 5-18 years, 1990 to 1999.	42 renal injuries due to sport, mainly in older children, 4.2 per year. No injuries required nephrectomy

A study of the western New York State Trauma Registry between 1993 and 2000 (Wan, Corvino, Greenfield, & DiScala, 2003a) found that in a sample of 4921 injured children aged 5-18 years, the incidence of recreational kidney injury was 6.9 per million children-years. Moreover, the incidence of catastrophic injuries requiring nephrectomy was only 0.4 per million children-years. The same authors (Wan, Corvino, Greenfield, & DiScala, 2003b) also examined data from the national pediatric trauma registry for the period 1990-1999. Among 81,923 cases, they found only 42 sport-related renal injuries (4.2 per year), none of which required nephrectomy.

Johnson et al. (2005) had similar findings in an analysis of the U.S. national pediatric trauma registry for the period 1995-2001. Of the 49,651 cases listed, 813 involved kidney injuries; 92 of these incidents were associated with cycling, and 88 with various types of sports participation. Based upon census reports of the U.S. population of children in 2000, the corresponding incidence rates for cycling and sports injuries were approximately 8 and 7 incidents per million children-years. However, only 4 of the sports injuries required nephrectomy.

A third study, from the San Diego pediatric trauma registry (McAleer, Kaplan, & LoSasso, 2002), examined 14763 incidents occurring between 1984 and 2000. The population involved was not specified, but there were a total of 113 sports-related renal injuries in this sample, a total of 7 per year; none resulted in nephrectomy, and none involved individuals with a solitary kidney.

The U.S. National Athletic Trainers' Association high school injury survey (Grinsell et al., 2006) analyzed data on 23,666 injuries among some 4 million athletic exposures from 1995 to 1997. This series included 18 renal injuries, but none resulted in nephrectomy or any known loss of renal function. The risk of renal injury for high-school students was set at 2.3 injuries per

million exposures in male basketball players, and 2.6 per million exposures in male soccer players, with corresponding figures for girls of 2.5 and 6.0 injuries per million exposures. These risks were two orders lower than those for head and spinal injury.

A thirty-year survey from Skaraborg County, Sweden (Bergqvist, Hedelin, Karlsson, Lindblad, & Mätzsch, 1982) found approximately 8 sport-related renal injuries per million person-years, although the authors commented that the incidence appeared to be rising over the study period (1950-1979), perhaps because of a growing popularity of active recreation. Two nephrectomies and 1 heminephrectomy were required over the course of this survey.

A small study examined the severity of sports-related renal injuries, finding 5 of 6 bicycle related injuries and 1 of 8 sport-related incidents were relatively severe (Grade IV or V)(Gerstenbluth et al., 2002).

Additional evidence on the relative safety of sport participation comes from the American Organ Procurement and Transplantation Network. In December of 2011, 96,000 patients were awaiting a renal transplant, but not one of the injuries had arisen during sports participation (Grinsell et al., 2006).

We may conclude that the risk of renal injury during active pursuits is extremely low, that more injuries are sustained unsupervised activity than in most forms of organized sport, and that only a small proportion of sport-related injuries are sufficiently severe as to require a nephrectomy.

Factors modifying the inherent risk of recreation-induced renal injury

Possible factors modifying the inherent risks of renal injury during sport and active recreation include the wearing of protective equipment, initial renal health, age, and the presence of a solitary kidney.

Protective equipment: Although the U.S. National Kidney Foundation and the Kidney and Urology Foundation of America have each advocated the use of protective padding as a means of protecting a solitary kidney, equipment is custom-made, and the cost is high (>US $350). Moreover, although the use of such equipment may appear logical, there is as yet no good epidemiological evidence that it is effective (Psooy, 2006).

Initial renal health: A person with 2 healthy kidneys usually has a substantial renal reserve, and normal function may be maintained even after nephrectomy. However, the margin is much smaller with a single kidney, and the initial health of the remaining kidney becomes a significant issue (Mandell , Cromie, Caldamone, Eichelberger, & Betts, 1982). A much more cautious attitude to any type of sport is required if one or both kidneys are ectopic, multicystic, functionally impaired or obstructed.

Age: The kidneys are relatively larger in children than in adults, and they sometimes retain foetal lobulation, both factors making them more vulnerable to blunt trauma (Radmayr, Oswald, Müller, Höltl, & Bartsch, 2002). Vulnerability is further increased in young children because the rib cage is less rigid, and there is less soft tissue support (Styn & Wan, 2010).

Solitary kidney: A solitary kidney may hypertrophy until it is 50% larger than paired kidneys, and it faces a greater potential exposure to external trauma because of its greater size. A solitary kidney is also more vulnerable to irreversible damage from heat stress.and the temperature limits upon prolonged bouts of endurance exercise should be observed particularly carefully in those with a single kidney.

Conclusions: When assessing the risks of renal injury during sport, account should be taken of the efficacy of protective equipment, initial renal health, the age of the child, and the absence of one kidney. The solitary kidney is more vulnerable to heat stress, and because of hypertrophy is at greater risk of physical injury.

Sports with the greatest risk of renal injury

Many physicians have considered contact sports as particularly dangerous from the viewpoint of renal injury. Although some reviewers have argued against

this, in fact the available statistics show that contact sports are responsible for a substantial proportion of injuries (Table 3). However, because the total number of renal injuries is small and there are national differences in the popularity of various sports, the relative danger of various pursuits differs substantially from one study to another. Moreover, many of the studies on the relative risks of various physical activities apparently exclude injuries incurred when cycling, operating all-terrain vehicles, or engaging in playground recreation, although this is not always clear from the text.

Table 3. *Relative risk of various sports and physical activities.*

Author	Total sport-related renal injuries	Country & dates	Football	Soccer	Horse-riding	Ice-hockey	Snow-boarding	Skiing	Sledding	Cycling	Motor-cycle & all-terrain vehicles	Other sports
Bagga et al. (2015)	13,006	U.S., 2002-2010	16.6%	4.9%	7.3%			11.8%		17.8%	26.2%	17.8%
Bergqvist et al. (1982)	59	Sweden, 1950-1979		57.6%	8.5%	13.6%		8.5%		?	?	11.8%
Gerstenbluth et al. (2002)	14	Two U.S. trauma centres, pre 2002	7.1%			21.4$			14.2%	57.1%	?	
Grinsell et al. (2006)	465	Summary of 11 published papers	8.6%	7.3%				19.6%		20.4%	?	44.1%
Grinsell et al. (2012)	18	High-school surveillance, 1995-1997	66.7%	18.7%						?	?	18.7%
Johnson et al. (2005)	85	U.S., 1995-2001	23.5%	2.4%		3.5%	8.2%	8.2%	12.9%	Included in "other"	?	41.2%
McAleer et al. (2002)	98	Californian trauma registry, 1984-2000	6.1%		3.0%					27.6%	14.3%	49.0%*
Wan et al. (2003a)	15	U.S., 1993-2000	33.3%		6.7%	13.4%	6.7%	13.4%		6.7%	?	20.0%
Wan et al. (2003b)	42	U.S., 1990-1999	61.9%	4.8%		7.1%				?	?	26.2%
Wu & Gaines (2007)	115	U.S. 2000-2005	10.4%		3.5%		3.5%	4.3%		17.4%	11.3%	49.6%

* Including skate-boarding, roller-blading, use of playground equipment and miscellaneous falls

In an 18-year review of statistics for the U.S. National Football League, Brophy et al. (2008) found that the overall risk averaged 2.7 incidents of renal trauma per season. Further all of the affected individuals were able to return to play with both kidneys intact. About a third of the patients were hospitalized, but none required surgery. Although, incidents were 10 times more prevalent during actual games (0.000005 per exposure) than during practices, the authors of this report concluded that it may be safe for individuals with only 1 functioning kidney to play in the NFL. This verdict was accepted by 61% of NFL physicians, although their approval of participation in high school (450%) and college (50%) games was lower. A six-year study of Australian Rules football found that 13 cases of renal trauma had been admitted to one institution, with 2 requiring nephrectomy (Lee, Thavaeelan, & Low, 2004); unfortunately, this report did not indicate the corresponding number of exposures.

A study from Sweden (Bergqvist et al., 1982) found

a predominance of renal injuries among soccer players, particularly at the start of the season, when they were presumably in poorer physical condition. Likewise, a survey of high-school students found most of the renal injuries were in football (boys) or soccer (girls)(Grinsell, Butz, Gurka, Gurka, & Norwood, 2012), and two surveys of trauma-centre statistics found a concentration of renal injuries among football players (Wan et al., 2003 a, b).

A series of 14 sport-related renal injuries in Ohio (Gerstenbluth et al., 2002) included data on cycling; the bicycle proved responsible for 5 of the 6 high grade injuries (grade IV or V). McAleer et al. (2002) also found that cycling and the use of all-terrain vehicles were the major cause of renal injuries. This verdict was substantiated in a survey of 116 renal injuries from blunt trauma (Wu & Gaines, 2007). The commonest source of injury in this series was a motor vehicle collision (33 cases), with other causes including cycling (20 cases), use of all terrain vehicles (13 cases), limited contact sports (20 cases), contact sports (12 cases), alpine sports (9 cases) and horseback riding (4 cases). The use of all-terrain vehicles was also to blame for the most severe injuries, requiring nephrectomy. Interestingly, 2 of the 116 cases in this series were individuals with unilateral kidneys, and 3 other patients had abnormally positioned kidneys (Wu & Gaines, 2007). Among football players, the greatest risk was in pick-up games, when no protective equipment was worn (Wu & Gaines, 2007). One report where American football appeared more hazardous than cycling was from western New York State; possibly, cycling was less prevalent in this region than in California. Johnson et al. (2005) included data for cycling injuries in their survey, and they still found a substantial proportion of incidents were attributable to American football. However, none of the injuries needing nephrectomy were associated with contact sports; the specific causes of high-level renal damage were sledding (2 cases), downhill skiing (1 case) and roller-blading (1 case). Perhaps the most satisfactory evidence comes from the large surveys of Bagga et al. (2015) and Grinsell et al. (2012). Bagga et al. (2015) underlined the importance of cycling and sport vehicle related injuries, which together accounted for 44% of physical activity-related renal trauma, although American football and soccer together were also responsible for more than a fifth of injuries. Grinsell et al. (2012) put together data on 465 renal injuries from 11 articles; this analysis again found a substantial proportion of renal injuries were due to American football and soccer, although the totals for these sports were outweighed by cycling and skiing. In this series, the 14 incidents requiring nephrectomy were attributed to downhill skiing (5), cycling (4), horse-back riding (2), soccer (2), and American football (1).

Interpretation of much of this data is complicated by a lack of information on the number of hours of exposure to the various activities, but it does appear that risks are greater for some personal leisure pursuits than for most forms of organized sport.

Studies of specific sports

Possible factors influencing the risk of renal injury in any given type of sport or recreation include the level of competition, the individual's playing position, and possibly the availability of protective equipment. Simple precautions, including supervision by a coach or parents, are also likely to reduce the risk for many activities. A number of articles have looked at the risks involved in specific forms of active recreation, including the operation of all-terrain vehicles, cycling, alpine activities, and horse-back riding, although unfortunately in most reports the available data does not allow a calculation of the incidence of renal injuries.

All terrain vehicles: Consensus groups of pediatric surgeons in Canada and the U.S. have concluded that the operation of all-terrain vehicles by young and inexperienced children with inadequate protection is particularly dangerous in terms of renal trauma (Burd, 2009; Yanchar, 2008). Wu & Gaines (2007) emphasized

that dirt bikes and all-terrain vehicles were the most important sources of serious recreational injuries to the kidneys.

Cycling: A study of 107 serious cycling accidents found 30 head and neck injuries, and 18 that involved the abdomen; the 3 renal injuries were caused by impact with the ends of the handlebars (Winston et al., 1998). Current handle-bar designs seem very dangerous; 5 of 30 handlebar injuries involved the kidneys, and in 3 of these nephrectomy or hemi-nephrectomy was required (Sparnon & Ford, 1986). One study found 40 handle-bar injuries in 134,116 children attending a Swiss hospital; 1 of the 40 children concerned had sustained a renal rupture (Klimek et al., 2013). Another analysis of 1990 patients who had been injured when riding various types of vehicle with handle-bars found that 236 of these incidents (including 151 abdominal injuries) were due to the handlebars, but only 29 of these required a major operation (usually for small bowel perforation or pancreatic trauma rather than renal injury) (Nataraja, Palmer, Arul, Bevan, & Crameri, 2014).

Typically, the child loses control of the bicycle, and falls onto the end of the handlebars as the wheel rotates through 90 degrees. Possibly, this risk could be diminished by lessening the maximum rotation of the front wheel, altering the shape of the handlebars, and padding the ends of the handlebars or making them compressible (Acton et al., 1994; Clarnette & Beasley, 1997; Kubiak & Slongo, 2003). Other avoidable risk factors for the cyclist are an inappropriate size of bicycle for the child, and the use of stunt bicycles.

Alpine activities: The incidence of skiing injuries in Austria is about 1 per visitor-year, with 2% of these injuries affecting the kidneys (Radmayr et al., 2002). The Urology Department in an Innsbruck hospital treated 254 children for renal trauma over a 26-year period, mostly due to skiing incidents. In about a third of these patients, the renal injury was severe, but only 4 nephrectomies were needed (Radmayr et al., 2002). However, skiing carries a lower risk of abdominal injuries than snowboarding (Machida et al., 1999; Sulheim, Holme, RØdven, Ekeland, & Bahr, 2011); the abdomen accounted for 0.7% of injuries in skiers and 1.2% of snowboarders, with solitary renal injury accounting for 29.7% of abdominal trauma in skiers, and 68.4% in snowboarders (Machida et al., 1999). Most of the skiing injuries were sustained in the afternoons, possibly because of a deterioration in snow conditions. Problems were also more frequent in children, adolescents, and those with low skill levels, suggesting the value of lessons that embrace safety precautions (Goulet, Regnier, Grimard, Valois, & Villeneuve, 1999; Machida et al., 1999; Sulheim et al., 2011). In many skiers, other adverse factors were defective bindings, and the use of rented equipment (Goulet et al., 1999).

Sledding is also a fairly frequent source of renal injury. Factors increasing the risk for sledders include towing by a vehicle such as a snowmobile, sledding near to a road, and collision with a stationary object such as a tree (Shorter, Mooney, & Harmon, 1999). Five of 25 sledders admitted to a pediatric trauma centre had abdominal injuries, with 2 involving the kidneys, compared with 11 head injuries (Shorter et al., 1999).

Horseback riding: About 8% of injuries in horseback riding are abdominal, whereas 38% affect the face and head. A study of 315 injuries involving horses found that 8 involved the kidneys (Ghosh, DiScala, Drew, Lessin, & Feins, 2000). Children should stand clear of the horse's hooves, wear boots with heels (to minimize dragging after a fall) and ride a mount that is well-matched to their abilities (Jagodzinski & DeMuri, 2005). Many of equestrian injuries occur while grooming or walking beside a horse (Eckert, Lockemann, Püschel, Meenen, & Hessler, 2011).

Martial arts: Renal contusion can occur in sports such as jujitsu, judo and aikido, De Meersman &

Wilkerson (1982) found that 85% of judoka who fell 100 times on a 2.5 cm thickness mat developed significant haematuria (>50 red cells per high-powered field). However, the reported rate of renal injuries for martial arts is low, 1 of 5700 injuries sustained in 24,027 training years (Birrer, 1996). Safety in such sports can be enhanced by increasing the thickness of matting in the gymnasium, and possibly by use of spring-loaded mats (Itagaki & Knight, 2004).

Other sports causing renal injury: Case reports have identified other occasional incidents of renal trauma with many recreational activities, including a renal subcapsular haematoma induced by paint-gun pellets (Guerrero, Zhouy, El Sayed, Kouglas, & Lin, 2009),

Conclusions: Activities presenting higher than average risk of renal injury appear to include operation of all-terrain vehicles, cycling, alpine sports, horseback riding and martial arts. Individuals with single kidneys should observe particular care if they are involved in such pursuits.

Management of renal trauma

Management issues of concern in the context of the present review are the proportion of sport-related renal injuries that require nephrectomy, the duration of restricted activity following renal injury, the likelihood of a permanent impairment of renal function following trauma, and the advice on sports participation to give to parents.

Proportion of sport-related renal injuries requiring nephrectomy: Although the overall risk of renal trauma during sport is low, adverse consequences are further attenuated because the injuries are often quite minor, and can be managed conservatively, without long-term complications. One report found that 6% of injuries required abdominal exploration, and no more than 2% underwent nephrectomy (Buckley & McAninch 2011). Many of those who are injured can return to their chosen activity within as little as 2 weeks although severe lacerations may require several months away from competition (Brophy et al., 2008; Holmes, Hunt, & Sevier, 2003). Minor injuries are often assessed in terms of haematuria, although this does not provide a very reliable guide to the extent of renal injury (Patel et al., 2005; Radmayr et al., 2002; Santucci & McAninch, 2000).

In weighing the relative risks of various sports it is important to look at not only the total of reported renal injuries, but also their severity. Several non-contact sports such as cycling, skiing and snowboarding seem more prone to cause severe injuries, with a greater chance that nephrectomy will be required.

Duration of restricted activity: With a minor renal injury, the typical duration of restricted activity is 2-6 weeks. However, vigorous physical activity should be limited until haematuria has ceased (Bernard, 2009; Holmes et al., 2003).

Risk of permanent renal damage: Although the immediate recovery of the kidney from blunt trauma is usually both rapid and relatively complete, there have been suggestions of long-term sequelae (usually from subcapsular bleeding and pressure necrosis (Banowsky, Wolfel, & Lackner, 1970)), The resulting impairment of renal function is particularly troubling for the individual with a solitary kidney.

A review of 157 patients with renal agenesis found that as adults, even in the absence of athletic trauma, they were at increased risk of developing hypertension, proteinuria and renal insufficiency (Arguieso et al., 1992). A 3-year follow-up of 13 children with high-grade renal injuries found no signs of hypertension or other renal abnormalities (El-Shirbiny, Aboul-Ghar, Hafez, Hammad, & Nazeed, 2004). However, there have been suggestions, based upon technetium-99m-dimercaptosuccinic acid renal scans suggests, that severe (Grade 5) renal trauma can ultimately cause renal

scarring and a loss of parenchymal tissue that impairs renal function (Keller et al., 2004). Further information is needed on the extent of this risk.

Advice to parents: Having weighed the risks of a particular sport for a child with a single kidney, the physician has the responsibility of communicating the level of risk to the parents. While the physician should underline the need to minimize dangers to the child, it is also important to health and normal overall development that an excess of caution does not deprive the child of interesting options for involvement in health-promoting physical activity.

Although the risk of renal injury for most types of sport and recreational activity is very low, it is not non-existent. One way of communicating the level of risk to parents is to compare kidney and head injuries. For most sports, the danger is at least 5 times higher for head than for renal injury (Psooy, 2006 2009); however, the potential for head injuries is not usually considered a reason to prohibit a child from involvement in all sport.

At the same time, there are simple precautions that can greatly reduce the risk of renal injury, as discussed above, and it is particularly important that these precautions be communicated to the parents if a child has only a single kidney.

Limitations of current information.

There remain many significant gaps in current knowledge concerning the dangers of sport participation for the individual with a single kidney. The risks remain poorly defined, because many of the available statistics lack critical information on the number of hours of exposure to the activity per year; moreover, some analyses appear to exclude exposure to informal activities such as cycling. A greater risk of injury might be anticipated for a hypertrophied single kidney, but this is not apparent in the available data; is this because there is a lesser exposure to physical activity in those with a single kidney? The use of haematuria as a means of detecting persistent renal injury seems to be unreliable, and there is a requirement for a simple but effective tool that can assess the recovery process following renal trauma. More information is also needed on the immediate vulnerability to heat stress and the long-term incidence of hypertension in those sustaining serious renal injuries. Finally, there is a need for more precise evaluation of the efficacy of various types of equipment intended to protect against renal injury.

Conclusions

Systematic review suggests that many physicians are still overly cautious about recommending sport participation to children with single kidneys, while sometimes permitting more dangerous pursuits. Empirical evidence shows that the absolute risk of renal injury during most types of physical activity is very low, although it is not entirely non-existent, for instance, there are 2.6 incidents per million exposures in male soccer players. Many of the renal injuries that are incurred during exercise are minor in nature, and only a small proportion require nephrectomy. Contact sports account for perhaps a fifth of all physical activity-related renal injuries. The operation of all-terrain vehicles, cycling, alpine sports and horse back riding are more common sources of renal trauma. Possible factors modifying inherent risks include parental supervision, the wearing of protective equipment, initial renal health, and the individual's age (children being more vulnerable than adults). Minor renal injuries may require only 2-6 weeks of restricted physical activity. Often, there are no long-term consequences to blunt renal trauma, although subcapsular haematomas can cause pressure necrosis, with later risks of hypertension, proteinuria and renal insufficiency. Sports physicians should emphasize that sport participation carries greater dangers for the head than for the kidneys, and that serious renal injury is more likely from motor traffic than from participation in

most sports. Moreover, doctors should underline the importance of continued regular physical activity to the overall health and development of the child. Nevertheless, those with a solitary kidney should avoid sports that involve contact or a high risk of collisions. Appropriate and effective protective equipment should also be worn, and activity patterns should be closely monitored by parents and coaches to avoid the taking of unnecessary risks.

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